ECN

Energy research Centre of the Netherlands

Applications of Energy Market Models in Europe

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ECN-Policy Studies

Mission: provides knowledge and strategies that matter for a sustainable future

- National energy and emission strategy
- Renewable Energy
- **Energy production, networks, and markets (EPM)**
- Energy in transport and buildings
- Energy Innovation and society
- International energy and climate issues

Optimization-based Energy Market Models of EPM

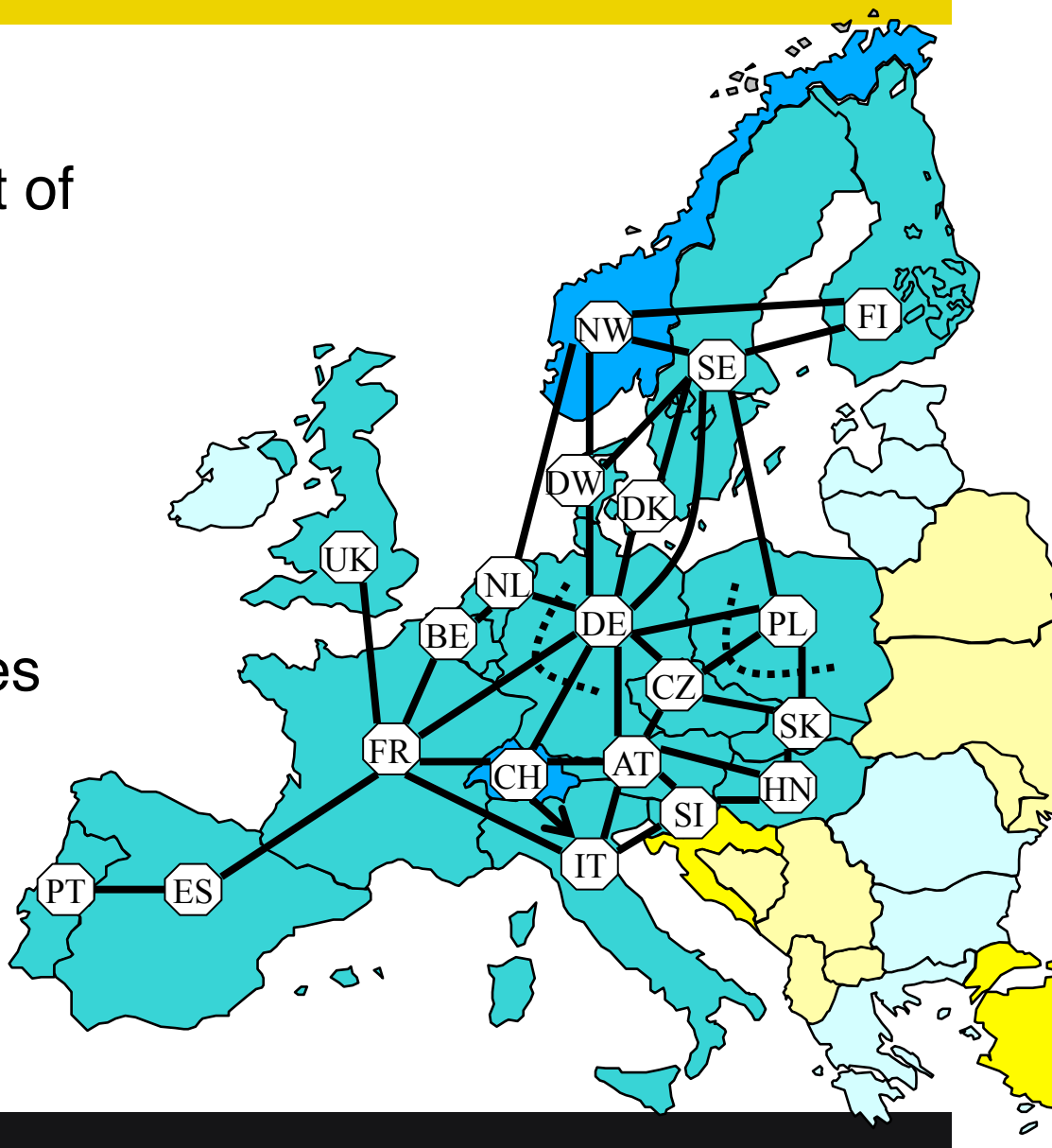
• Electricity market model of Europe: **COMPETES (**in cooperation with Benjamin F. Hobbs)

• Gas market model of Europe: **GASTALE (**in cooperation with Benjamin F. Hobbs and Steven Gabriel)

COMPETES

Goal: Evaluation of the impact of electricity market design & structure, regulatory changes and generator strategic behaviour upon:

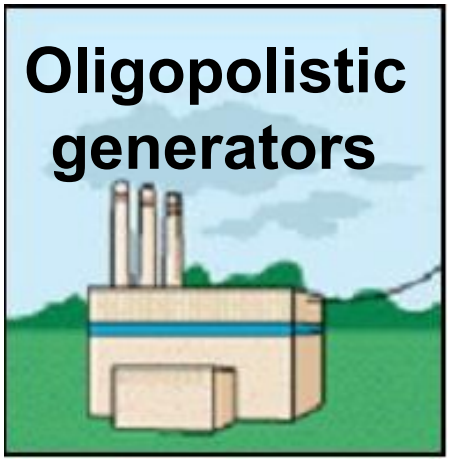
- Electricity market prices
- Cross-border congestion pattern and transmission prices between countries
- Income distribution (TSO revenues, generator profits, consumer surplus)

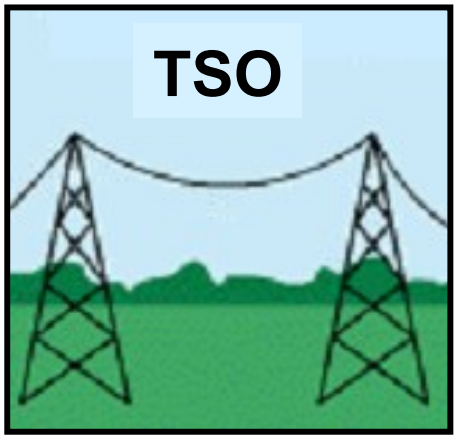


Market participants

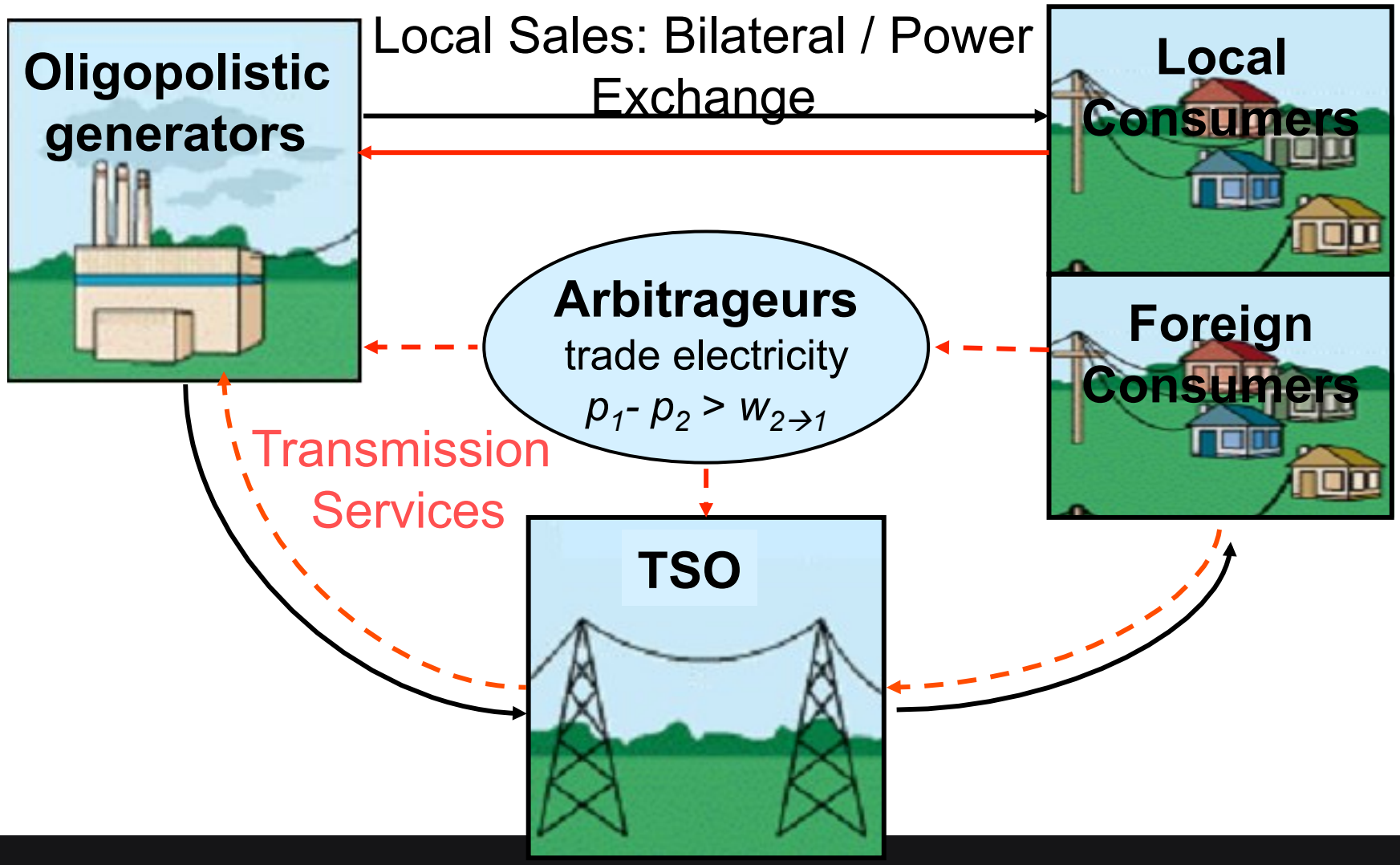
Agents:

- Generators aiming to maximize profits
- Arbitrageurs aiming to maximize profits
- TSO's aiming to maximize the value of transmission





Market interactions



Methodology (1)

- Competition between 20 EU electricity markets
- Short-run equilibrium
- Optimization problem for each agents: Generators, arbitrageurs, and TSOs:

⇩

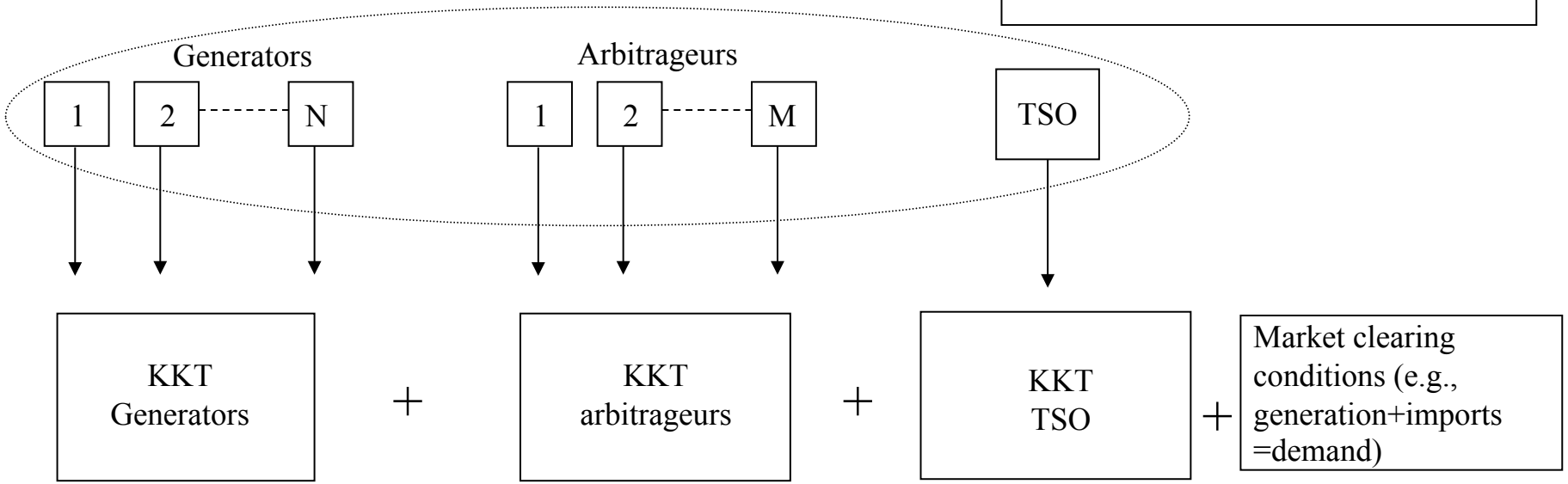
Optimality (KKT) conditions of all the agents and market clearing conditions

Methodology (2)

Agent i :

maximize $Revenue_i$-$Cost_i$

s.t. $Constraints_i$



Methodology (3)

- Competition between 20 EU electricity markets
- Short-run equilibrium (static model)
- Optimization problem for each agents: Generators, arbitrageurs, and TSOs:

⇩

Optimality (KKT) conditions of all the agents and market clearing conditions

⇩

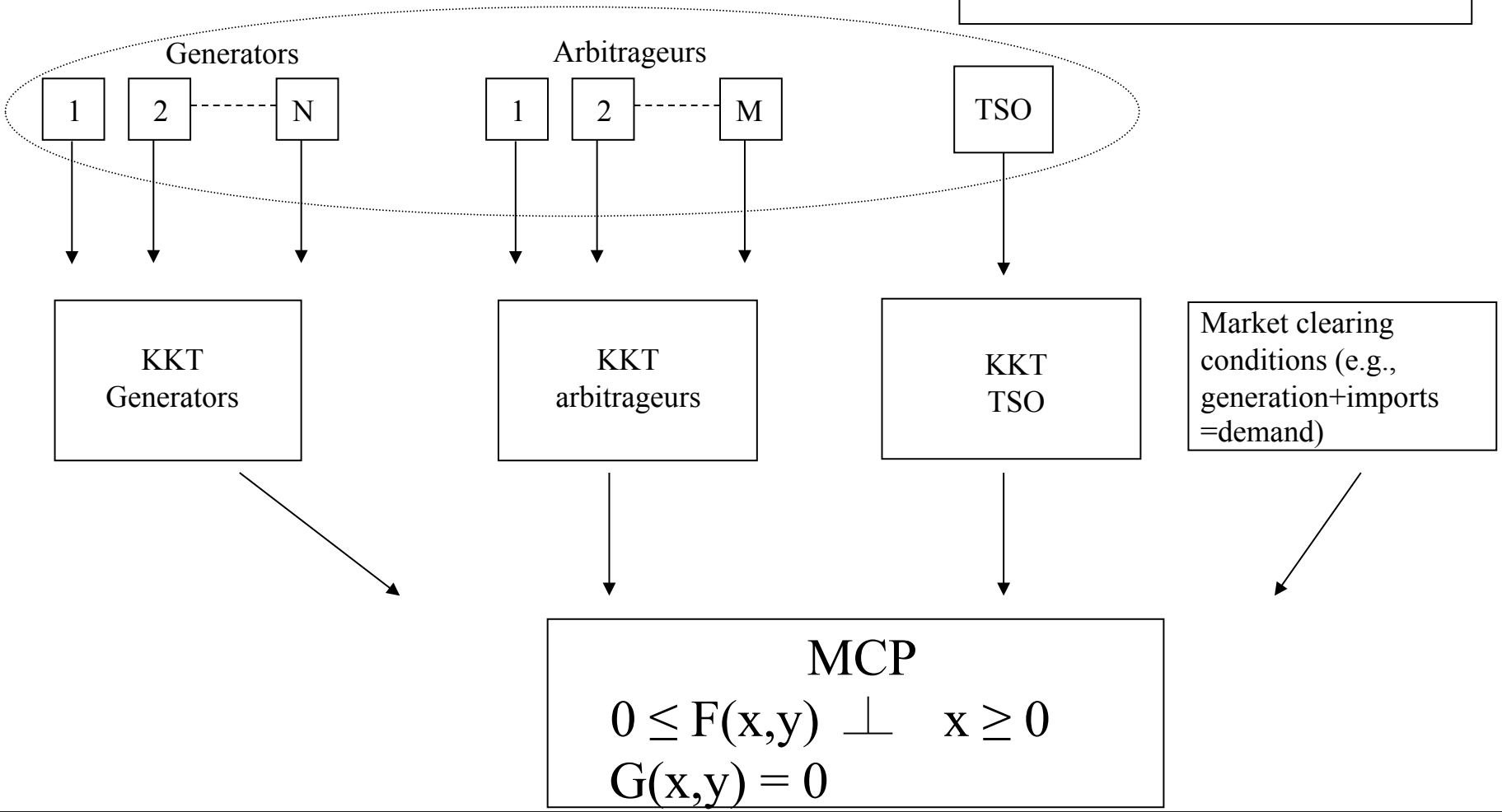
mixed complementarity problem (MCP)

Methodology (4)

Agent i :

maximize $Revenue_i$-$Cost_i$

s.t. $Constraints_i$



Methodology (5)

- Competition between 20 EU electricity markets
- Short-run equilibrium (static model)
- Optimization problem for each agents: Generators, arbitrageurs, and TSOs:

⇩

Optimality (KKT) conditions of all the agents and market clearing conditions

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mixed complementarity problem (MCP) | Optimization problem

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Solver (PATH) | NLP/LP Solver

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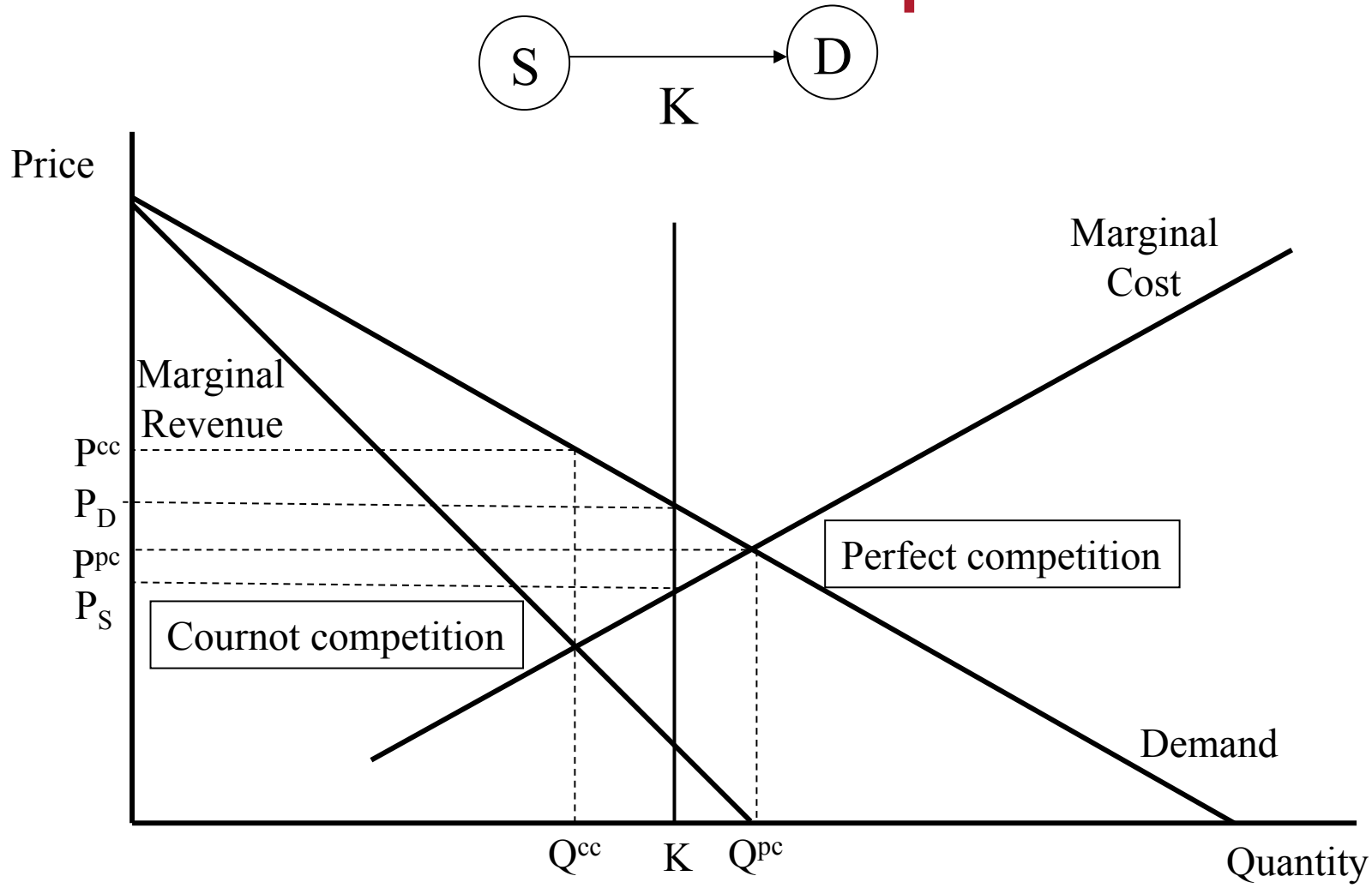
Equilibrium (Perfect competition or Cournot equilibrium)

How does it work for a simple market ?



Solution

Given specific levels of demand or demand curves, short-term marginal cost of supply and transmission capacities:

- allocation of generation capacity,
- allocation of transmission capacity
- electricity prices

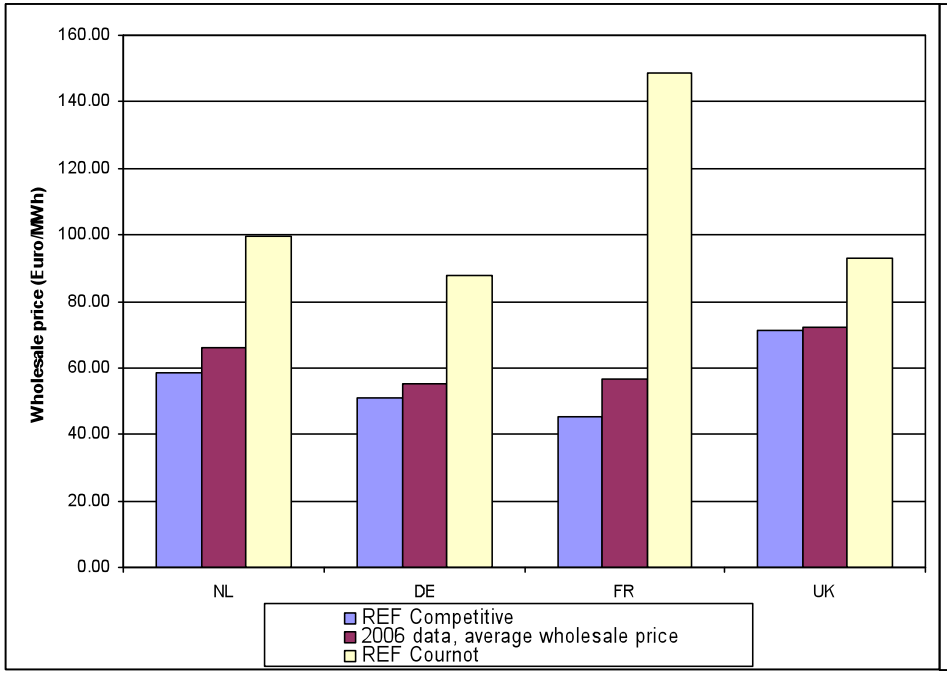
are determined either for Perfect competition or for Cournot equilibrium.

Input data

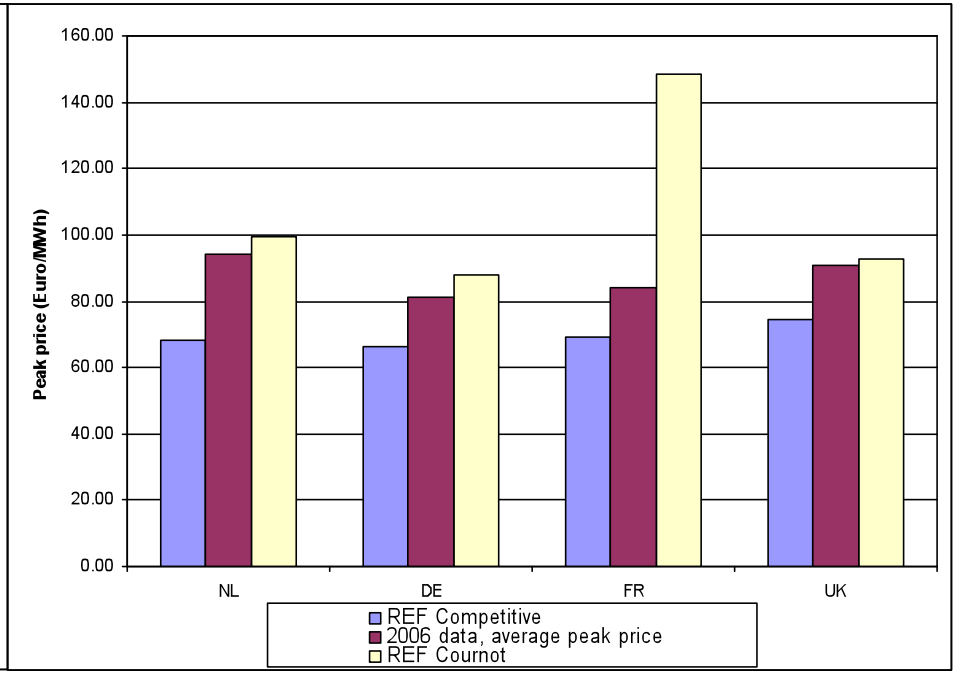
- individual power plants (ownership, fuel type, efficiency, availability, maximum output)
- transmission system (3-Hub system linearized DC approximation, auction-based transmission system)
- one year subdivided into 12 demand periods: winter, summer, midseason; super peak, peak, shoulder, off peak
- Wind production: seasonal variability->winter, summer, midseason

COMPETES Results vs Market Realizations for 2006

Average Base-Load Prices



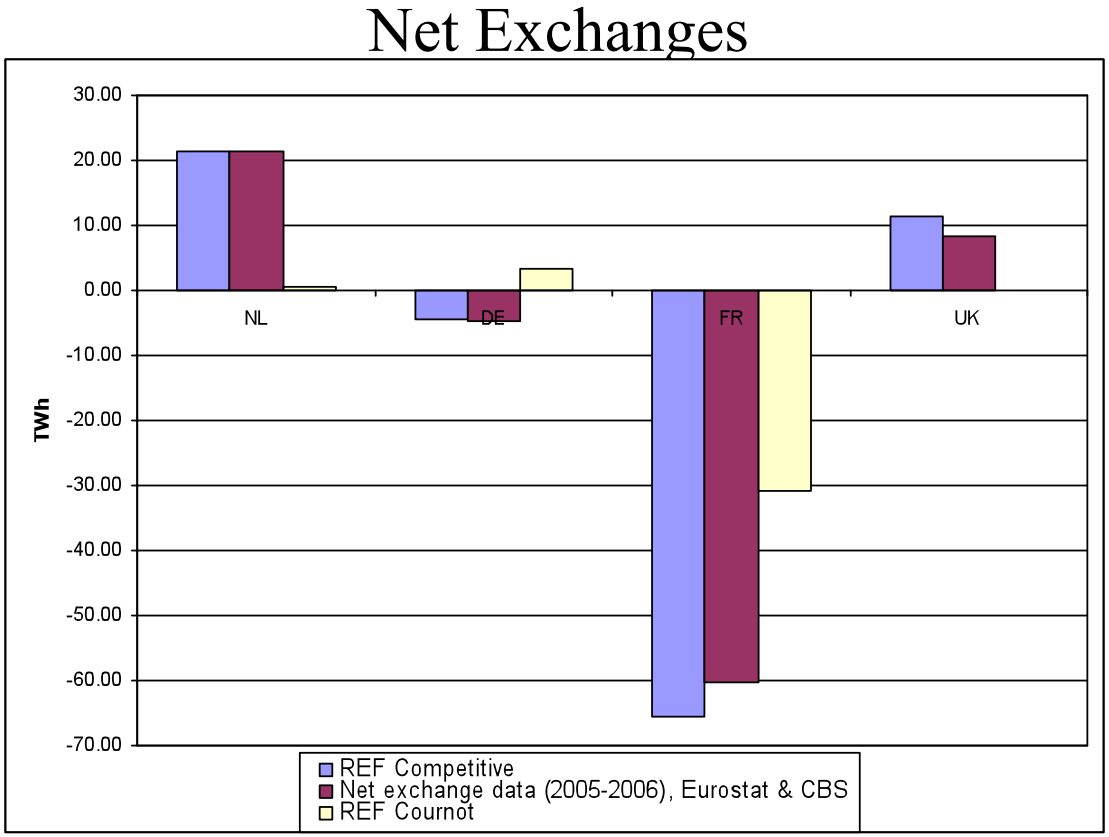
Average Peak-Load Prices



Wholesale prices in 2006 are close to base load prices in perfect competition

Peak Prices in 2006 are close to Cournot prices in peak hours (except France)

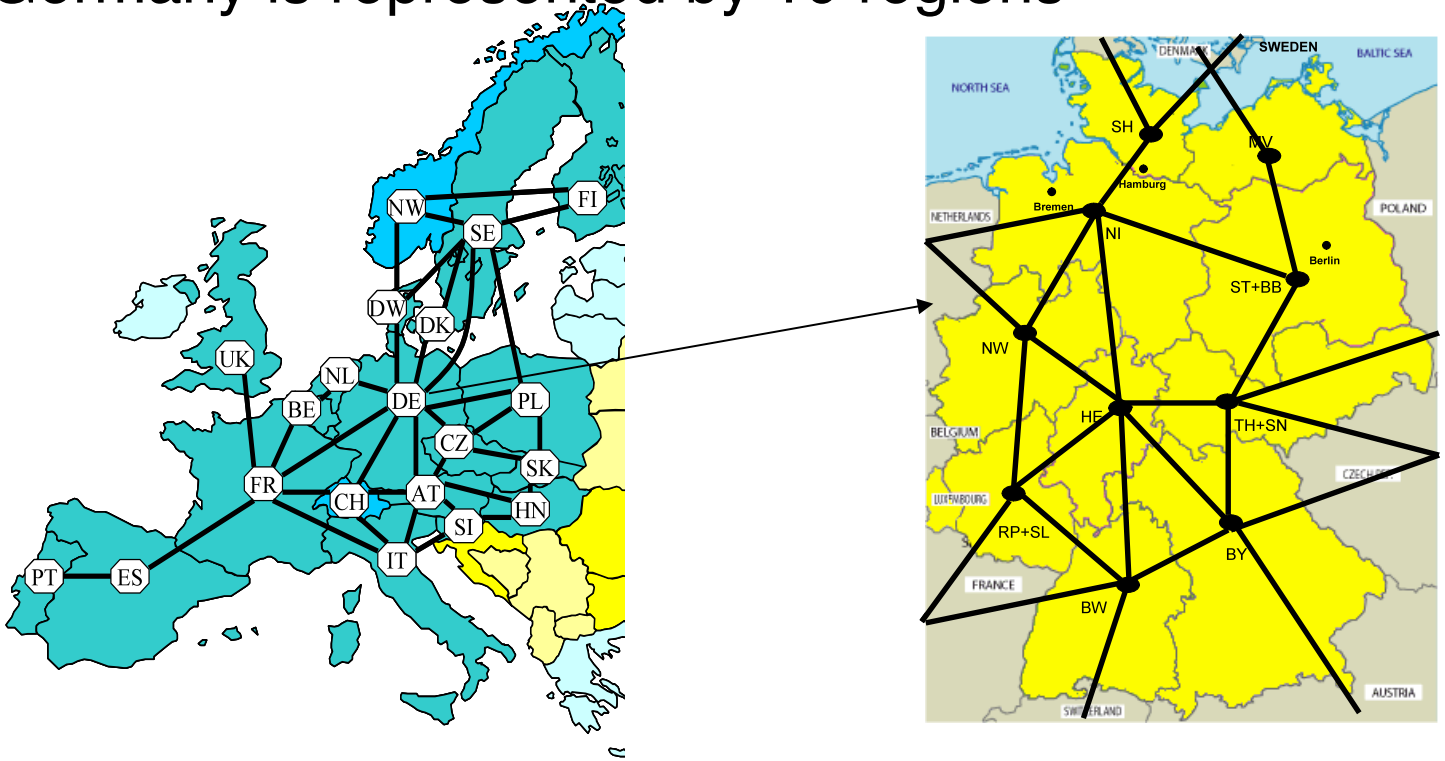
COMPETES Results vs Market Realizations for 2006



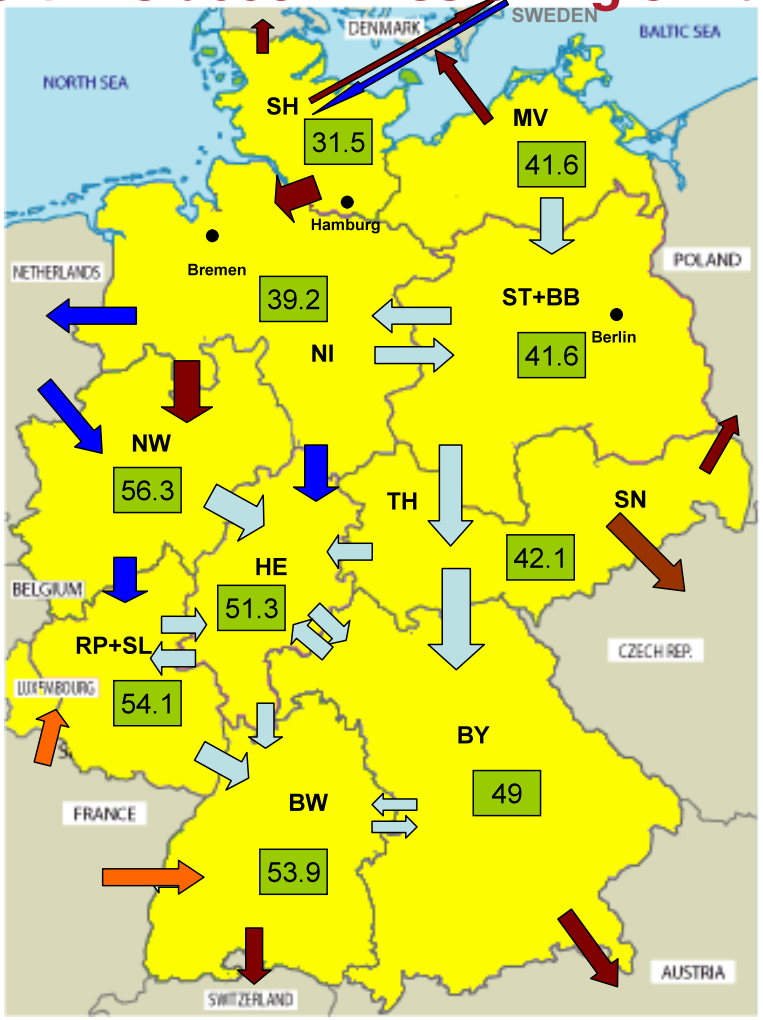
Net imports-exports in 2006 are close to net exchange flows under perfect competition

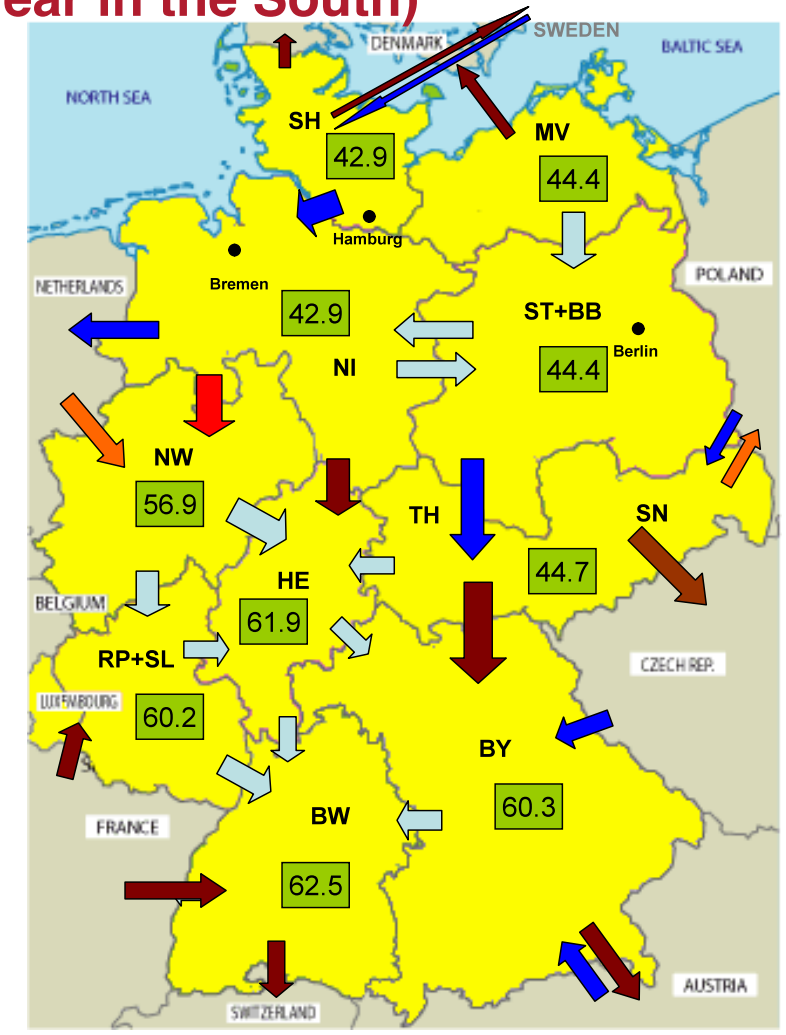
A nodal pricing analysis of the future German market

- Covers 20 EU countries; each country as a single node
- Germany is represented by 10 regions



Internal congestion in future German electricity market (Wind in the North vs decommissioning of nuclear in the South)





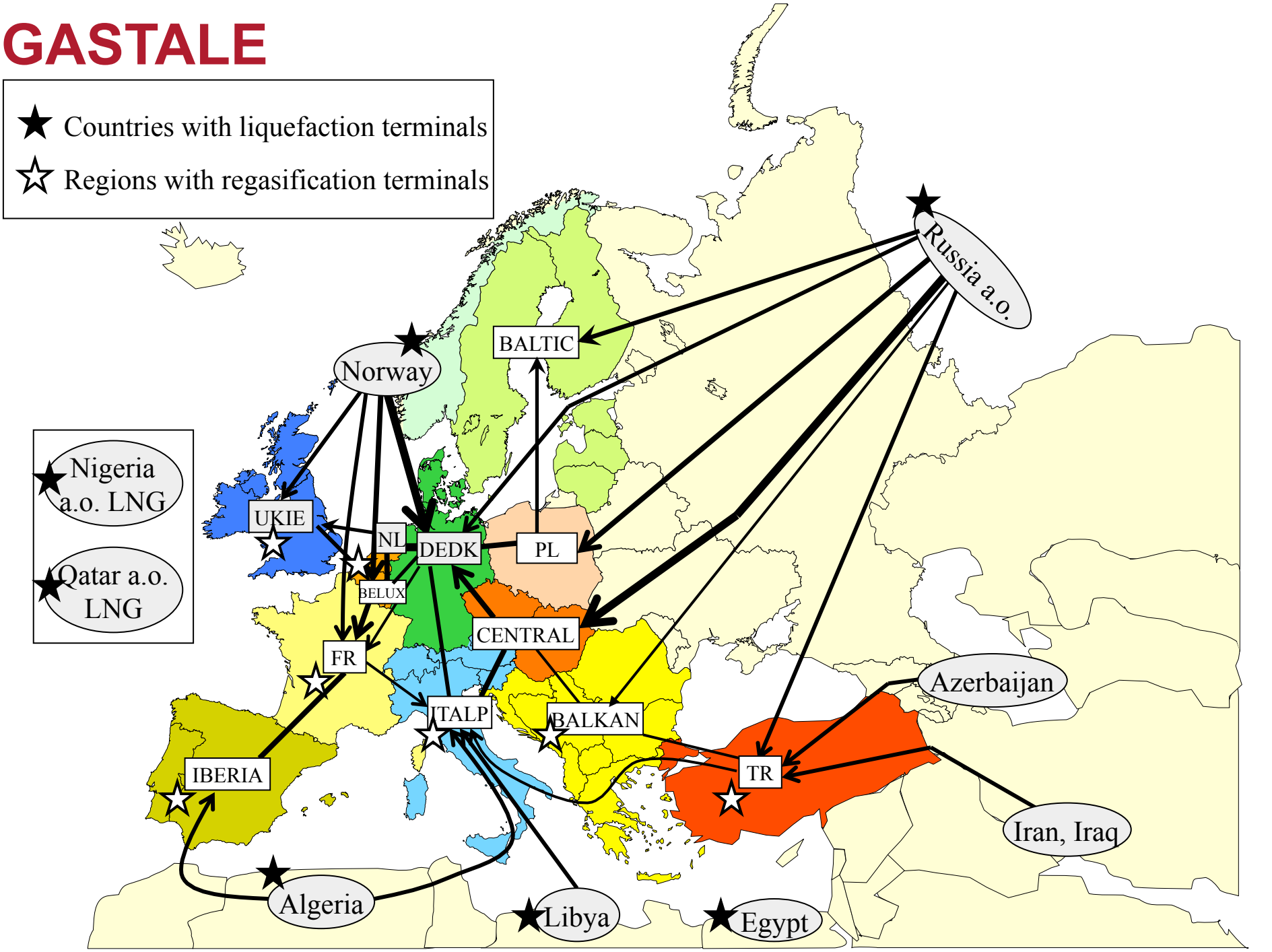
Possible Applications

- Impact of more or less stringent policies (e.g, CO_2 emission allowance, RES target and obligation levels on the market prices and the exchange flows between the national markets)

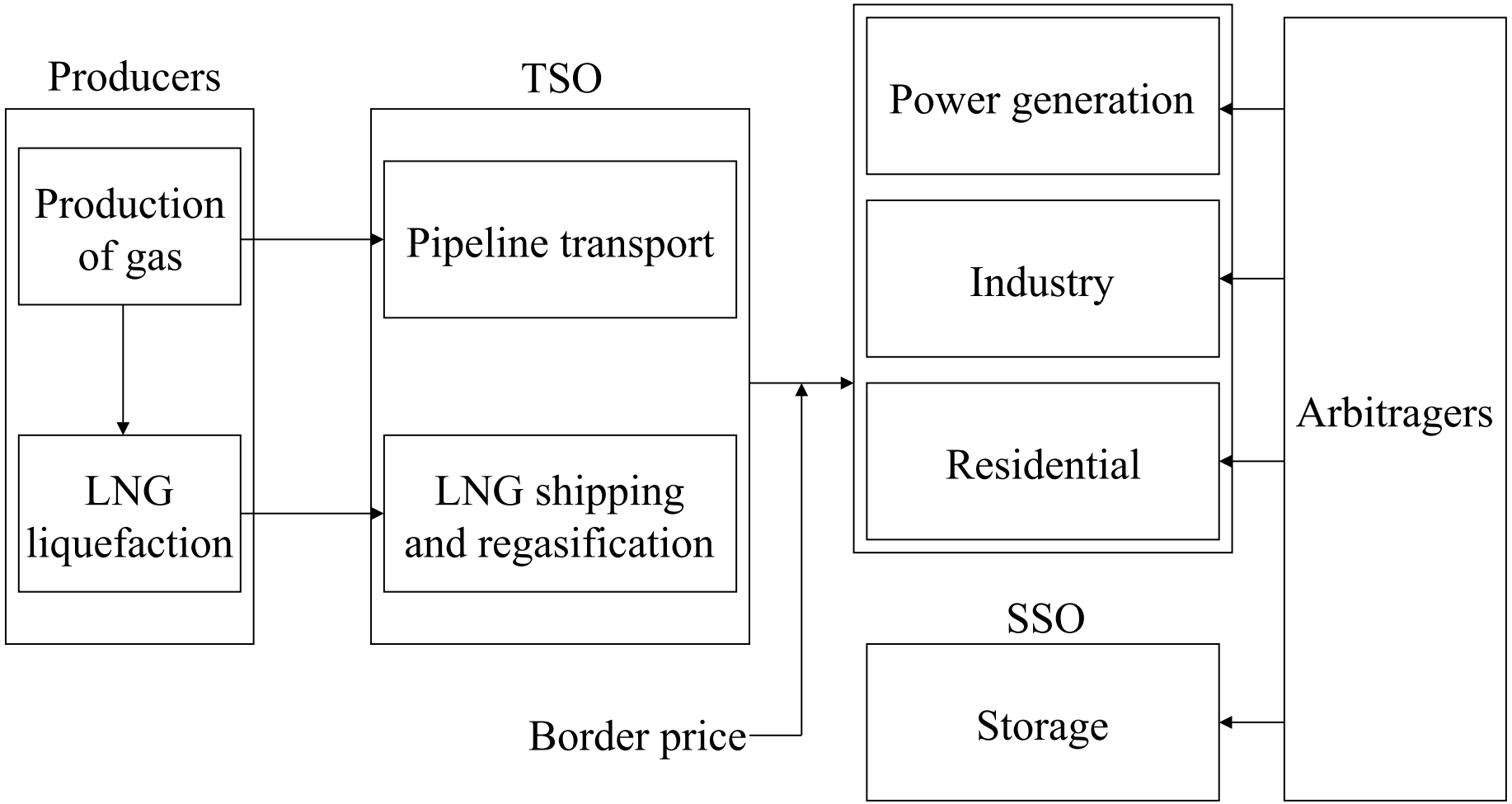
- Evaluation of impact of changes in power market
  - market structure (market integration)
  - investments in transmission and generation capacities

- Analysis of the potential consequences of mergers and acquisitions

GASTALE


Countries with liquefaction terminals
Regions with regasification terminals
Nigeria a.o. LNG
Qatar a.o. LNG
Russia a.o.
Norway
BALTIC
UKIE
NL
DEDK
PL
BELUX
CENTRAL
FR
ITALP
BALKAN
Azerbaijan
IBERIA
TR
Iran, Iraq
Algeria
Libya
Egypt

The Overview of Market Participants



Model Features

1. Multiyear equilibrium model formulated by MCP
2. Solver: PATH
3. Time Resolution:
   - Horizon 2010-2050
   - Time steps: ten year periods
   - For each period: low, medium, and high demand season
4. Investment dynamics:
   – Short-sighted view: Economically optimal expansion of pipeline, LNG and, storage capacities for each ten year period
   – Perfect foresight is also possible
5. Producers behavior vary between perfect and Cournot competition->Cournot conjectural variation

Possible Applications

Based on gas demand projections (e.g., European energy and transport trends, International Energy Agency (IEA) scenarios)

- Seasonal gas prices
- Investments in gas infrastructure (pipeline, storage, and LNG capacity)
- Security of supply (e.g, dependence on the gas supply of non-EU countries)

Wish list and challenges

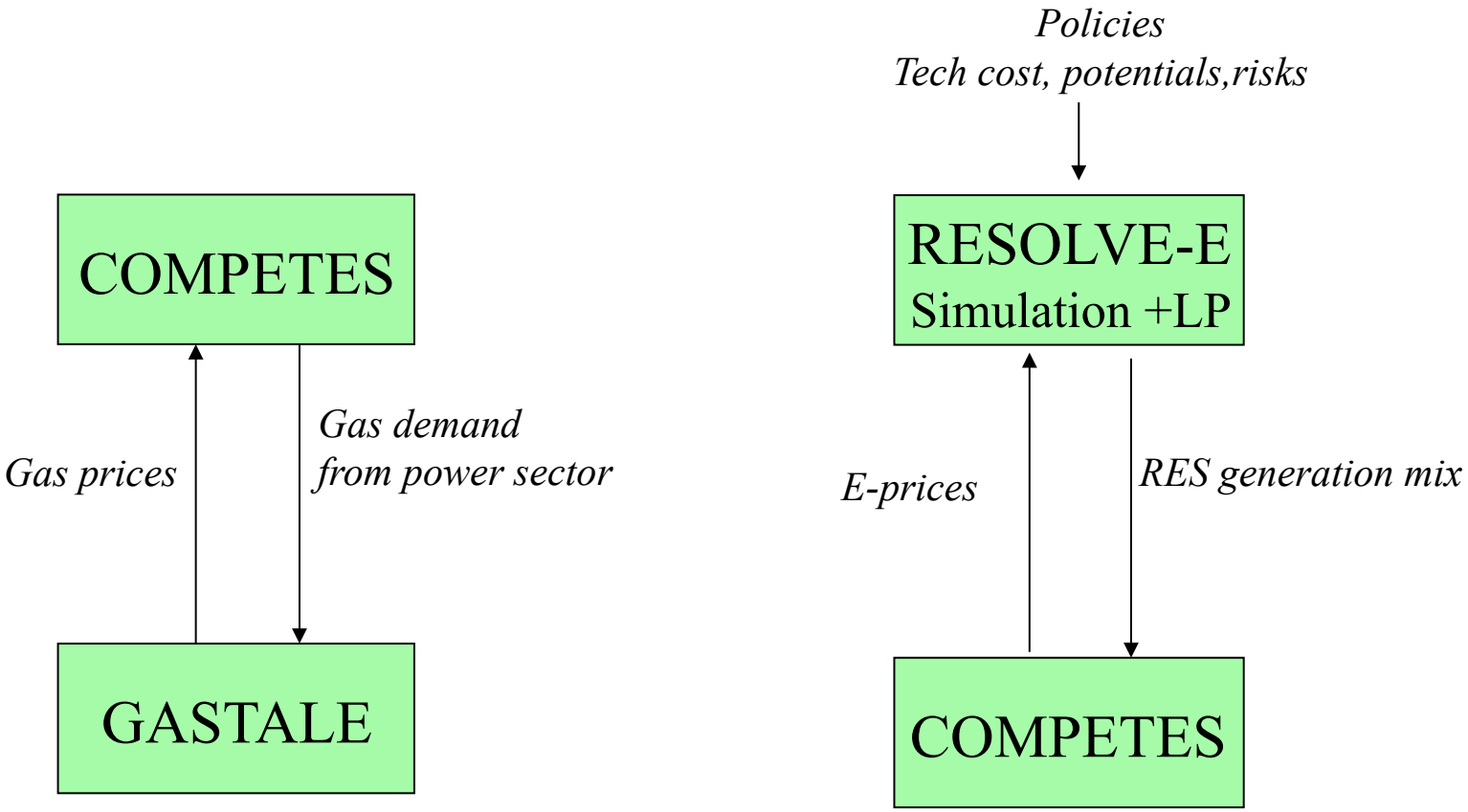
1. Future Electricity markets: Large scale optimization/complementarity problems
   - Incorporating wind intermittency
   - Geographical coverage
   - Endogenous investment decisions (reserve capacity and transmission capacity)

Wish list and challenges

1. Future Electricity markets: Large scale optimization/complementarity problems
   - Incorporating wind intermittency
   - Extended spatial dimension
   - Endogenous investment decisions (reserve capacity and transmission capacity)

Wish list and challenges

2. Interactions between market models: Convergence to a solution?



THANK YOU!